



***Urban Vulnerability to Climate Change: A system
dynamics analysis.***

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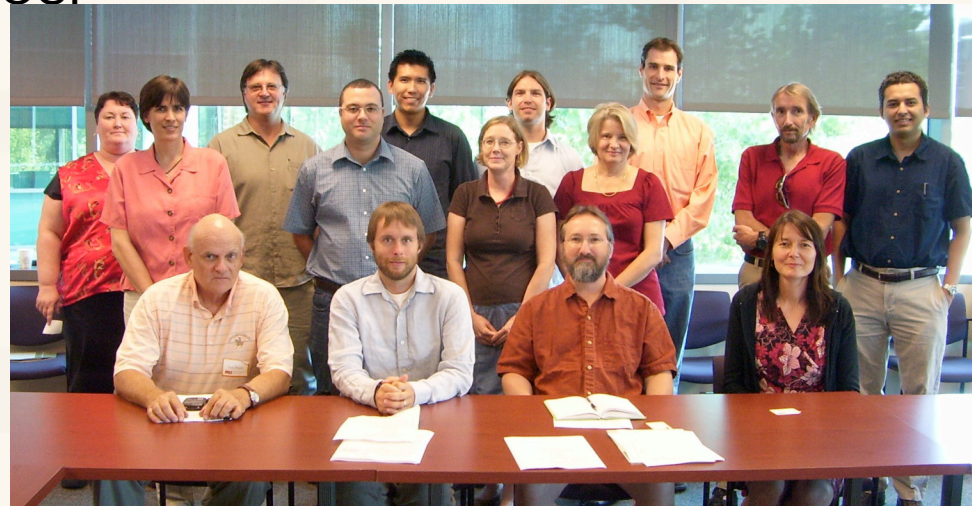
***NASA Ames Research Center
Workshop on Sustainable Urban Development
Jan 9-10, 2009***



Collaborators:

- Funded through NSF Coupled Natural and Human Systems program
- Award period: Oct. 2008 – Feb. 2012
- Collaborators:

Sharon Harlan (PI): Sociology; Susanne Grossman-Clarke (Co-PI): Climate Modeling; Will Stefanov (Co-PI): Remote Sensing; Chris Martin (Co-PI): Landscape Ecology; Tim Lant (Co-PI): Mathematics/Decision Theater/GIOS.





First, we celebrated.





Extreme Heat and Health

- ☐ *Exposure to excessively warm weather threatens human health in all types of climate regimes.*
- ☐ *Heat kills and sickens multitudes of people around the globe every year – directly and indirectly.*
- ☐ *Climate change, coupled with urban development, will impact human health.*
- ☐ *Phoenix is an ideal laboratory for studying urban heat islands under extreme climate conditions.*
- ☐ *Social factors are critical in vulnerability analysis.*



Cities, Neighborhoods, Climate Vulnerability

- ❑ Landscapes denuded of vegetation in poor neighborhoods expose residents to the elements.



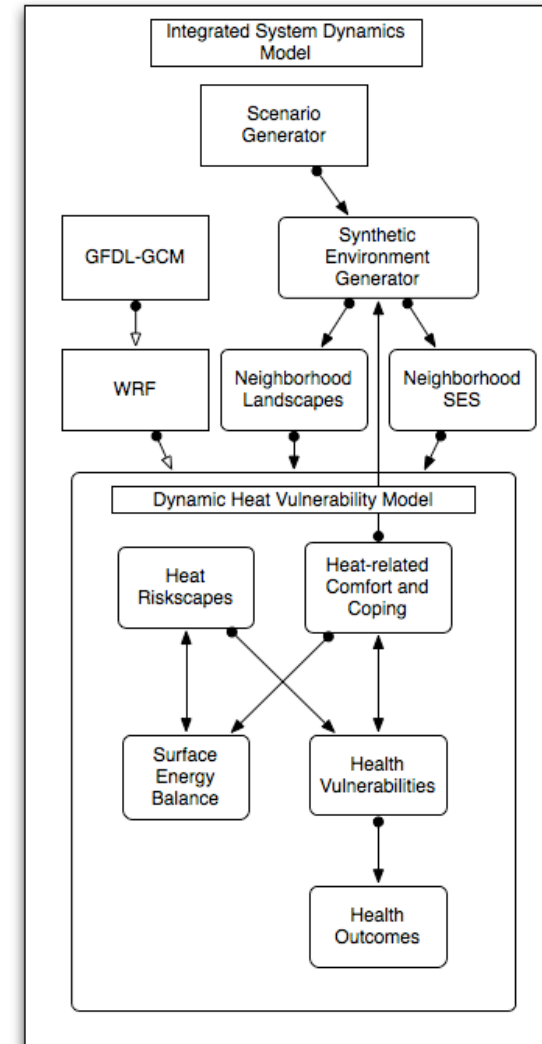
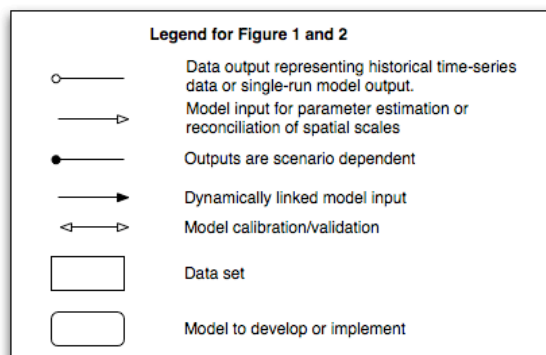
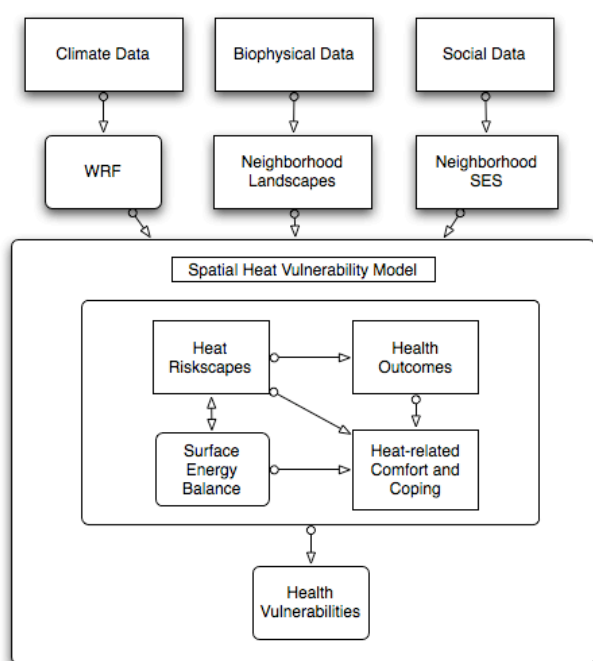


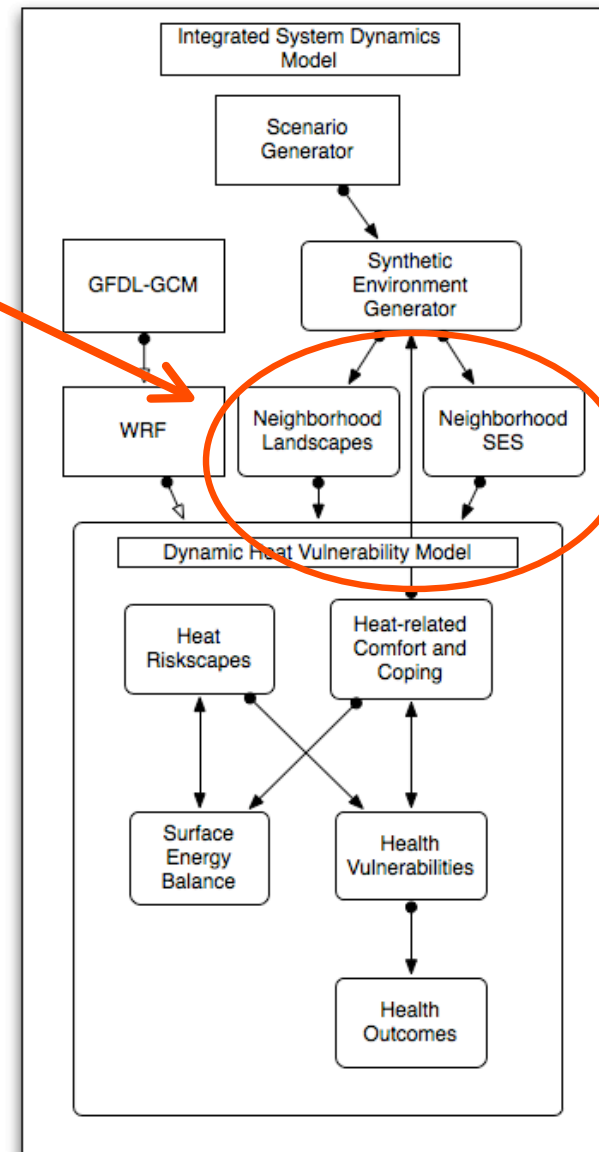
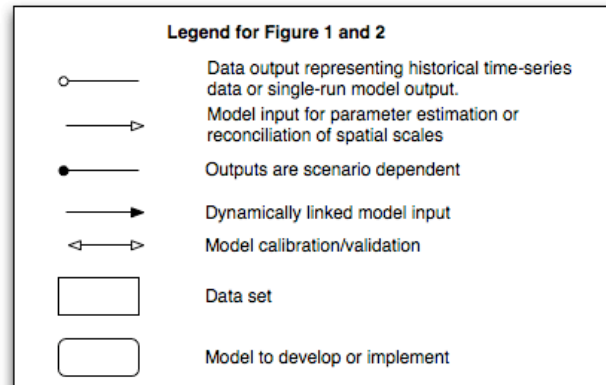
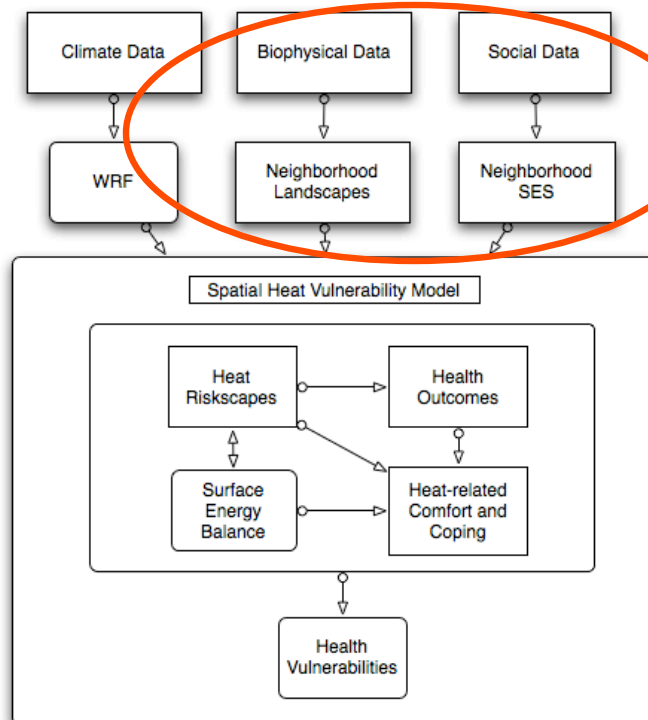
Research Questions

- 1) How does the spatial structure of heat “riskscapes” change through time and how are “riskscapes” related to changes in urban landscape cover characteristics, seasonal variations in local climate, global climate, and residential segregation?
- 2) How have residentially segregated neighborhoods, increasing environmental and social inequalities, and heterogeneous heat “riskscapes” rendered low-income and racial/ethnic minority populations disproportionately vulnerable to heat-related health hazards?
- 3) How will heat-related health vulnerabilities be distributed across particular places and population subgroups in the future?



System Dynamics approach





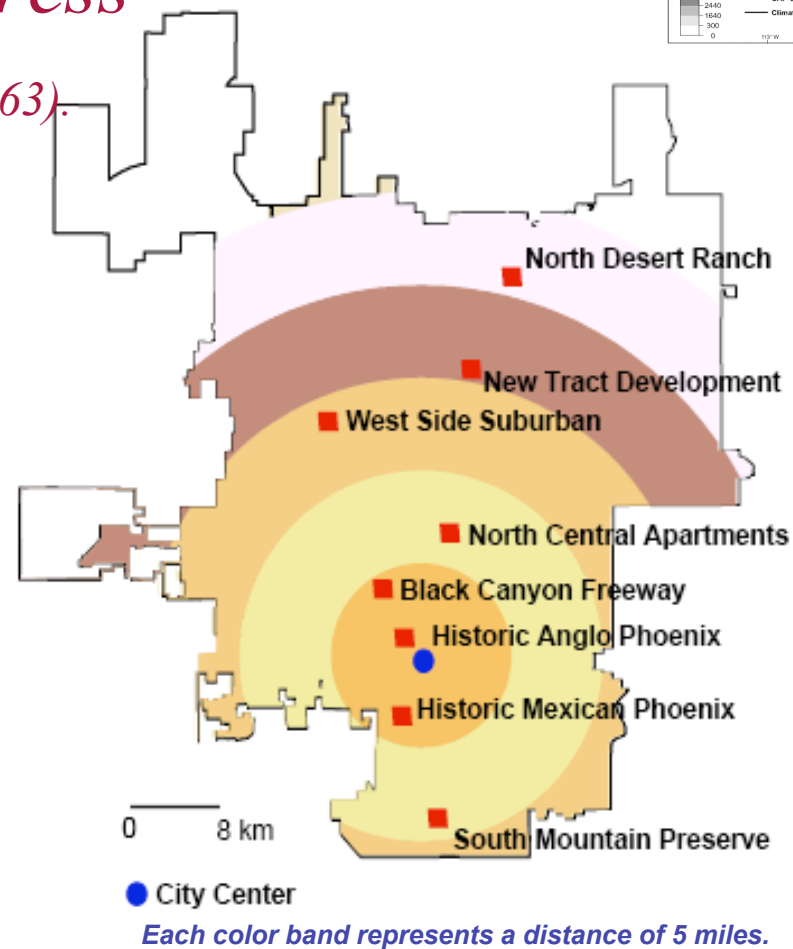
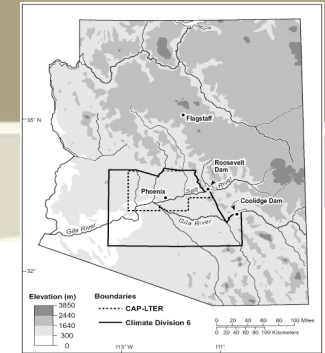


Neighborhood Microclimates & Vulnerability to Heat Stress

(Social Science & Medicine 63: 2847-2863).

2000 Census block groups co-located with CAP LTER ecological monitoring sites. Selected for variation in income, ethnicity, location, and landscape.

- Lower, middle, and higher-income*
- Located in the urban core, suburbs and fringe*
- Age of housing and landscape types vary*





Demographic Characteristics by Exposure Intensity Class of Neighborhoods

US Census	Low	Medium	High
N Neighborhoods	15	10	15
<i>Size</i>			
Population per sq mi	3,569	3,757	7,550
<i>Income</i>			
Household income	\$71,903	\$62,669	\$38,621
<i>Ethnicity</i>			
% minority	20.7	25.9	44.7
<i>Age</i>			
% ages 65 and over	9.8	20.4	17.5

Census Block Group (2000)



Black Canyon Freeway

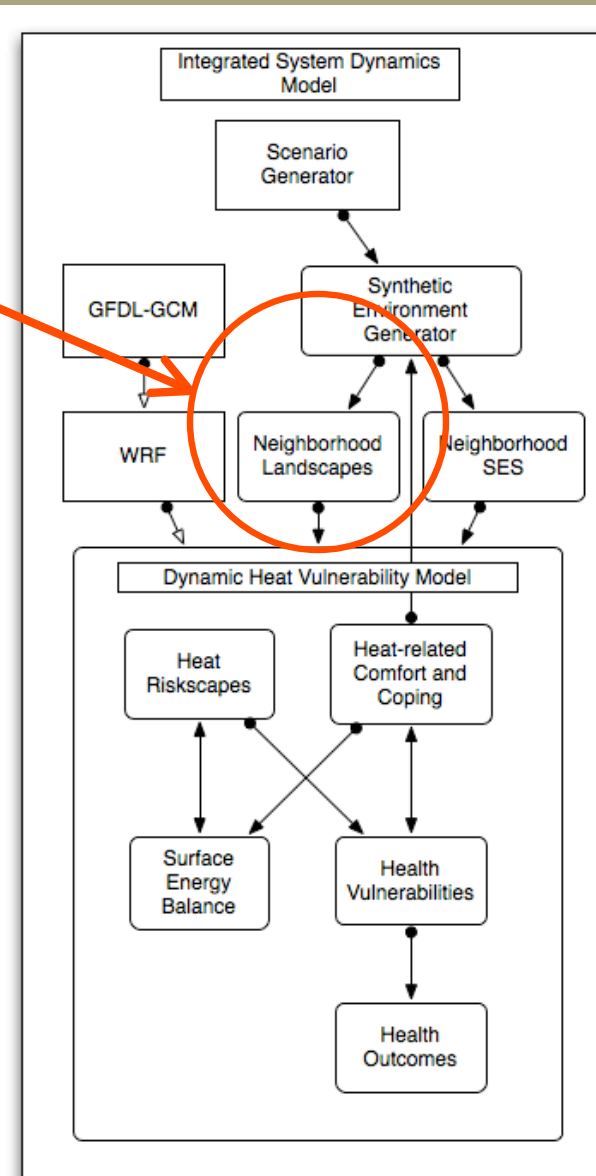
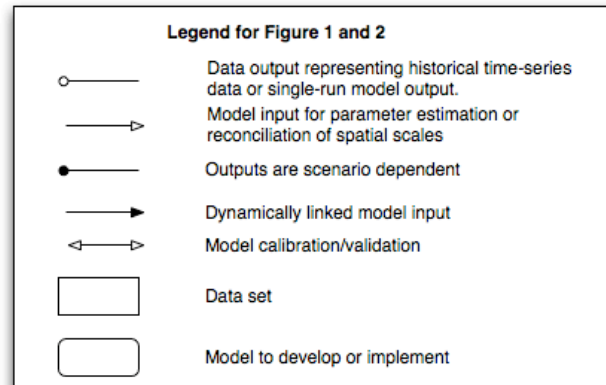
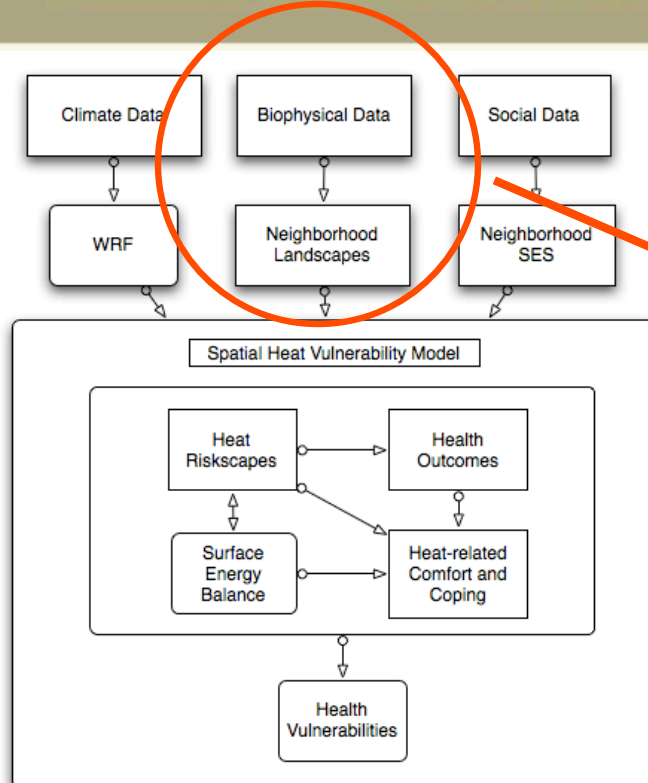


0 0.1 0.2 0.4 Miles

ERSITY

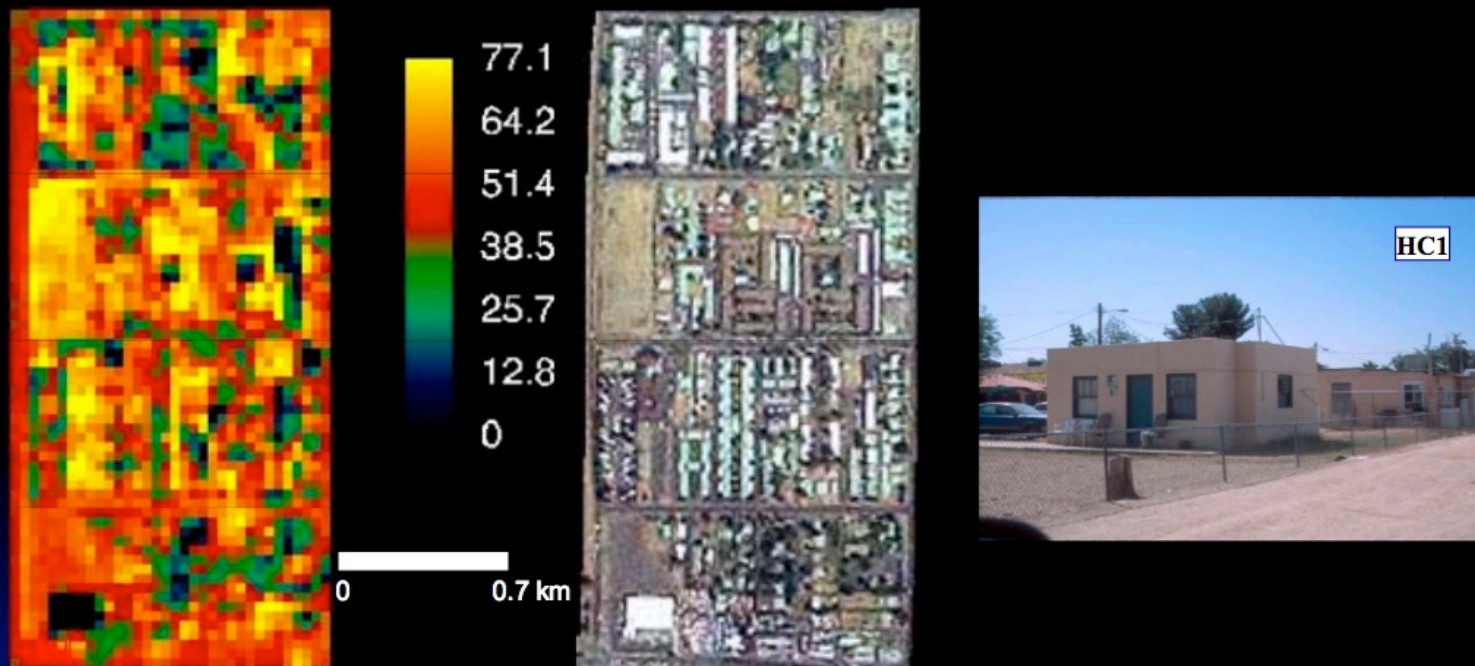
*Neighborhood Conditions, 2003 Heat Wave (July 12-16), 5:00 pm*

Neighborhood	Mean (sd) Air Temp	Mean (sd) Human Thermal Comfort Index	Increase in HTCI During HW	Pct Summer 2003 Hours => 200 HTCI
Historic Anglo Phoenix	40.2 (3.1) 104F	186 (35)	28	4.2
North Desert Ranch	43.3 (2.7)	215 (37)	49	5.9
West Side Suburban	43.7 (2.7)	220 (37)	45	11.0
South Mountain Preserve	44.4 (2.6)	226 (35)	50	15.9
North Central Apartments	44.5 (3.1)	226 (44)	48	18.4
Historic Mexican Phoenix	45.6 (2.9)	245 (37)	49	14.8
New Tract Development	45.5 (3.1)	238 (44)	45	22.2
Black Canyon Freeway	47.7 (3.4) 118F	259 (42)	62	19.8
Mean: All	44.4 (2.3)	227 (28)	47	14.0
Difference: highest - lowest	7.5	73	44	18.0
ANOVA	F=22.98***	F=5.94***	ARIZONA STATE UNIVERSITY	





Surface Temperature Measurement using MASTER airborne sensor

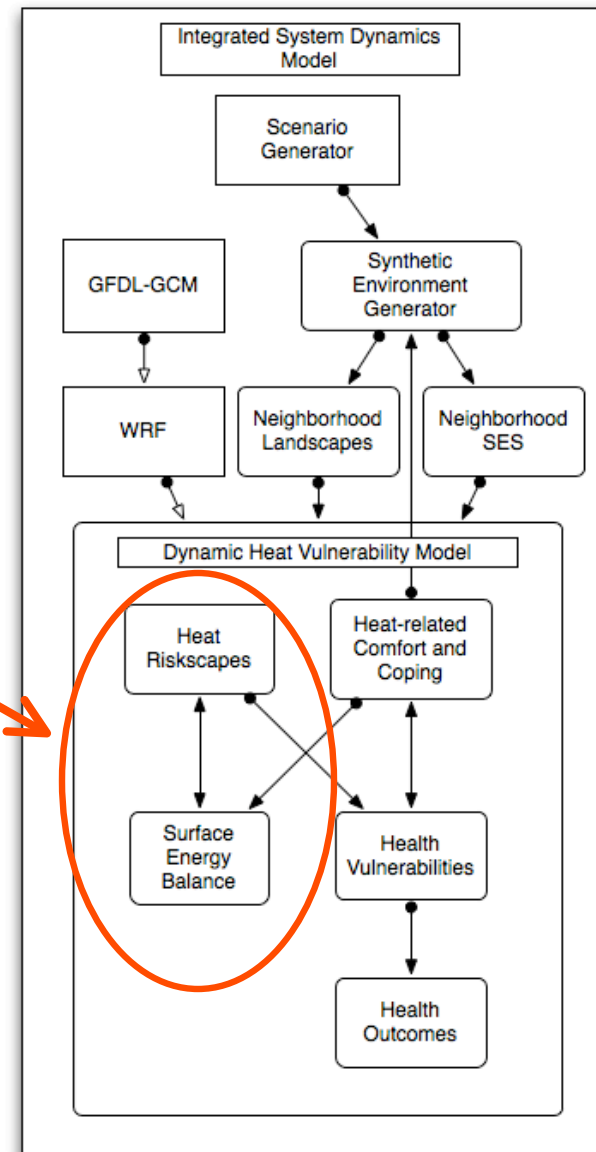
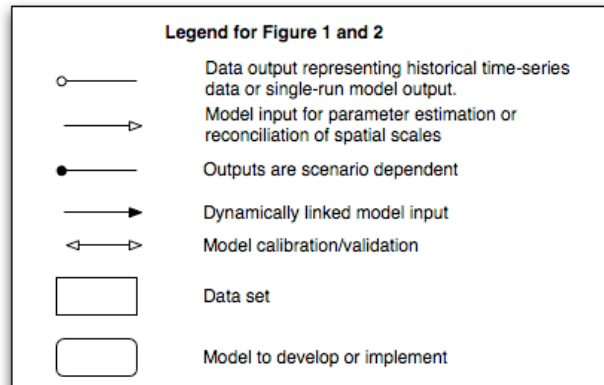
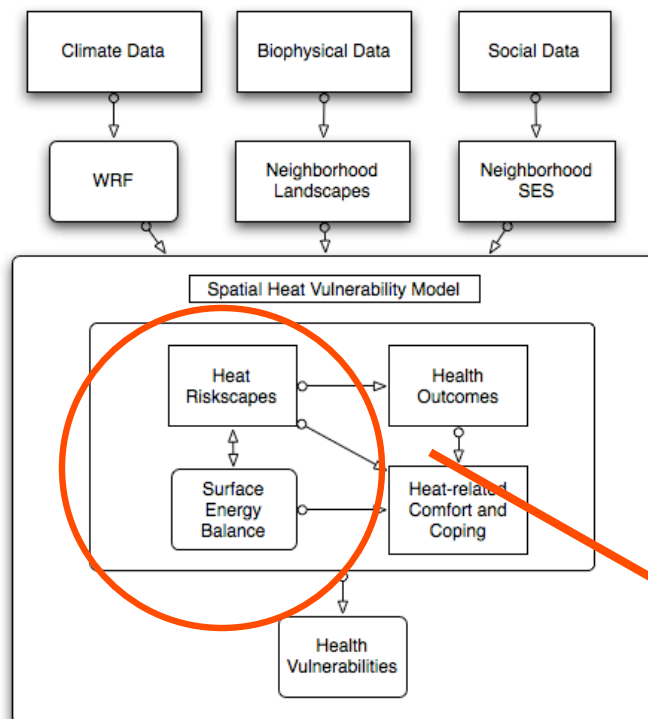


Left - MASTER surface T; Right - 3 m/pixel digital aerial orthophotography

iTunes

NSF Urban Climate Grant Team Meeting, ASU, 9/26/08

Credit: Will Stefanov



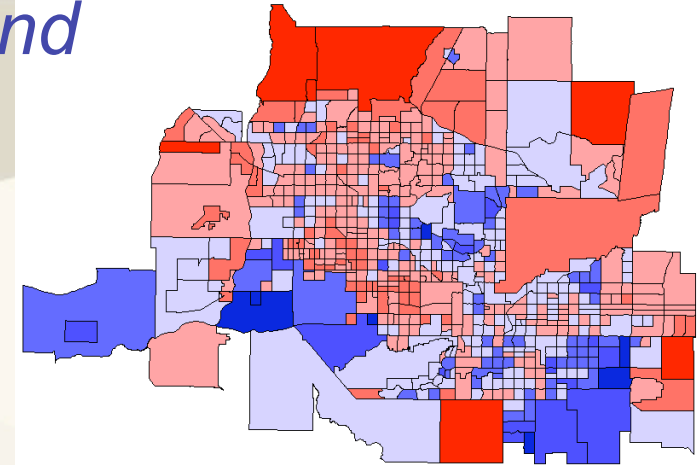
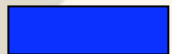


Regional Societal, Vegetation, and Climate Relationships

How is urban warming associated with vegetation?

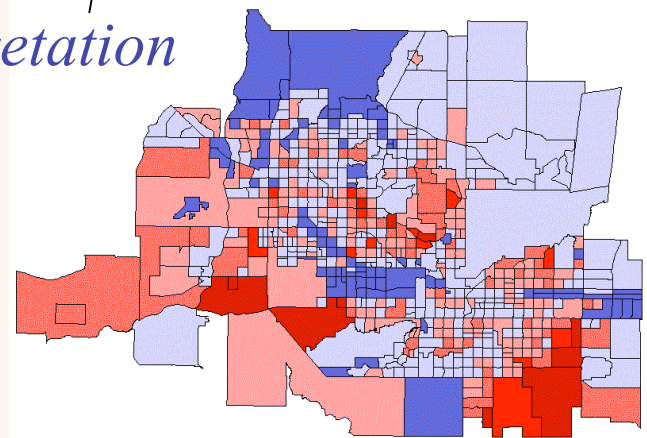


Increasing Variable



Temperature

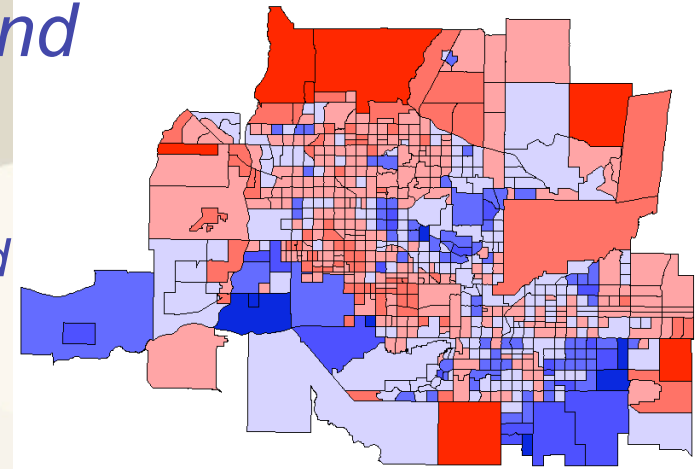
Vegetation





Regional Societal, Vegetation, and Climate Relationships

*How are warming and vegetation associated
With socio-economic status?*

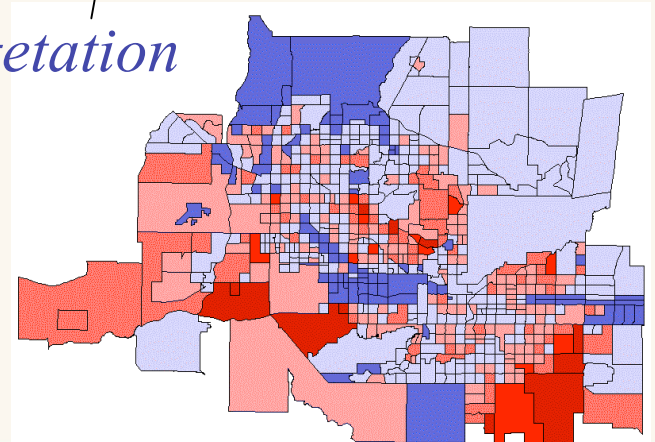
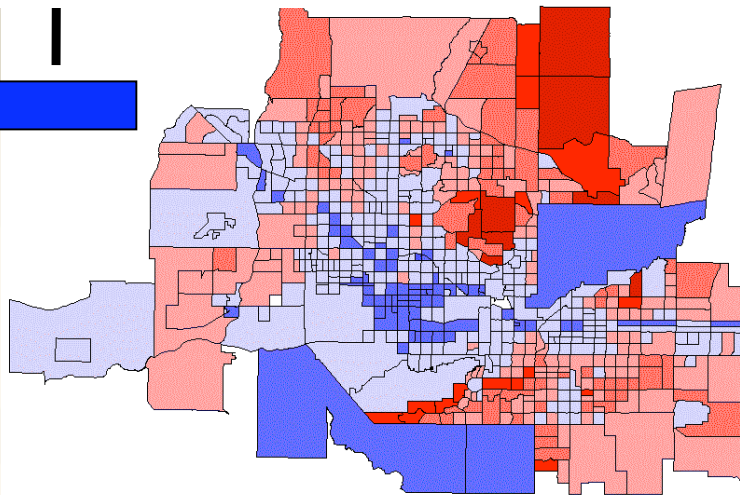


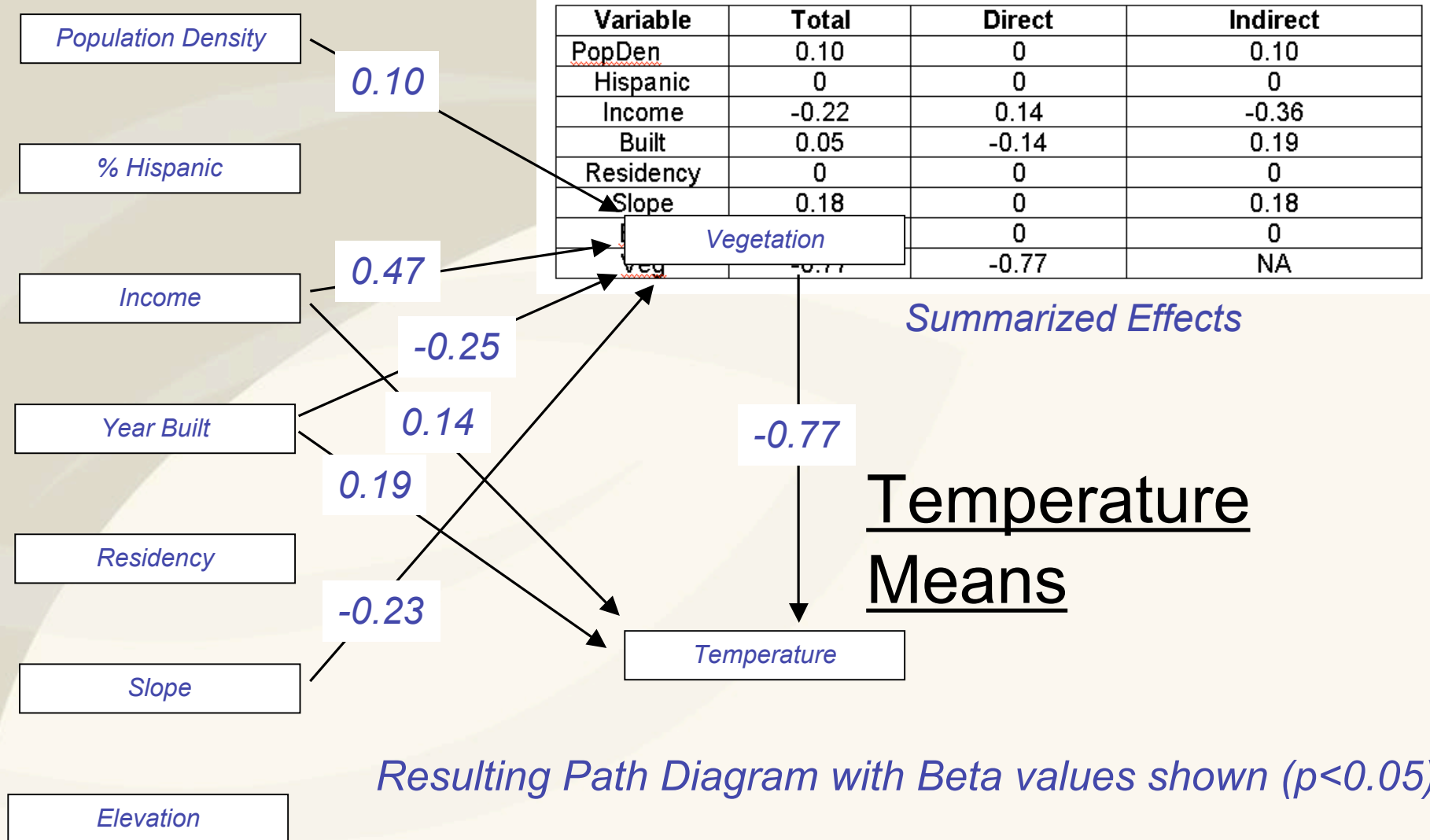
Income

Temperature

Vegetation

Increasing Variable





Resulting Path Diagram with Beta values shown ($p < 0.05$)

Jenerette, G.D., S.L. Harlan, A. Brazel, N. Jones, L. Larsen, and W.L. Stefanov. 2007. Regional relationships between vegetation, surface temperature, and human settlement in a rapidly urbanizing ecosystem. *Landscape Ecology* 22:353-365.



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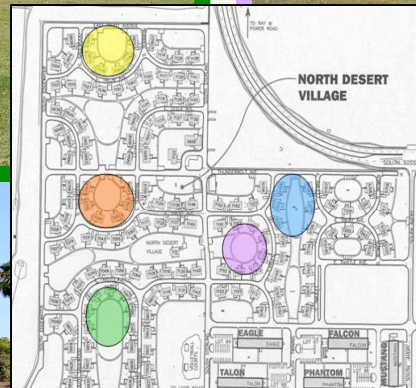
North Desert Village Experiment



+ water



+ water



+ water

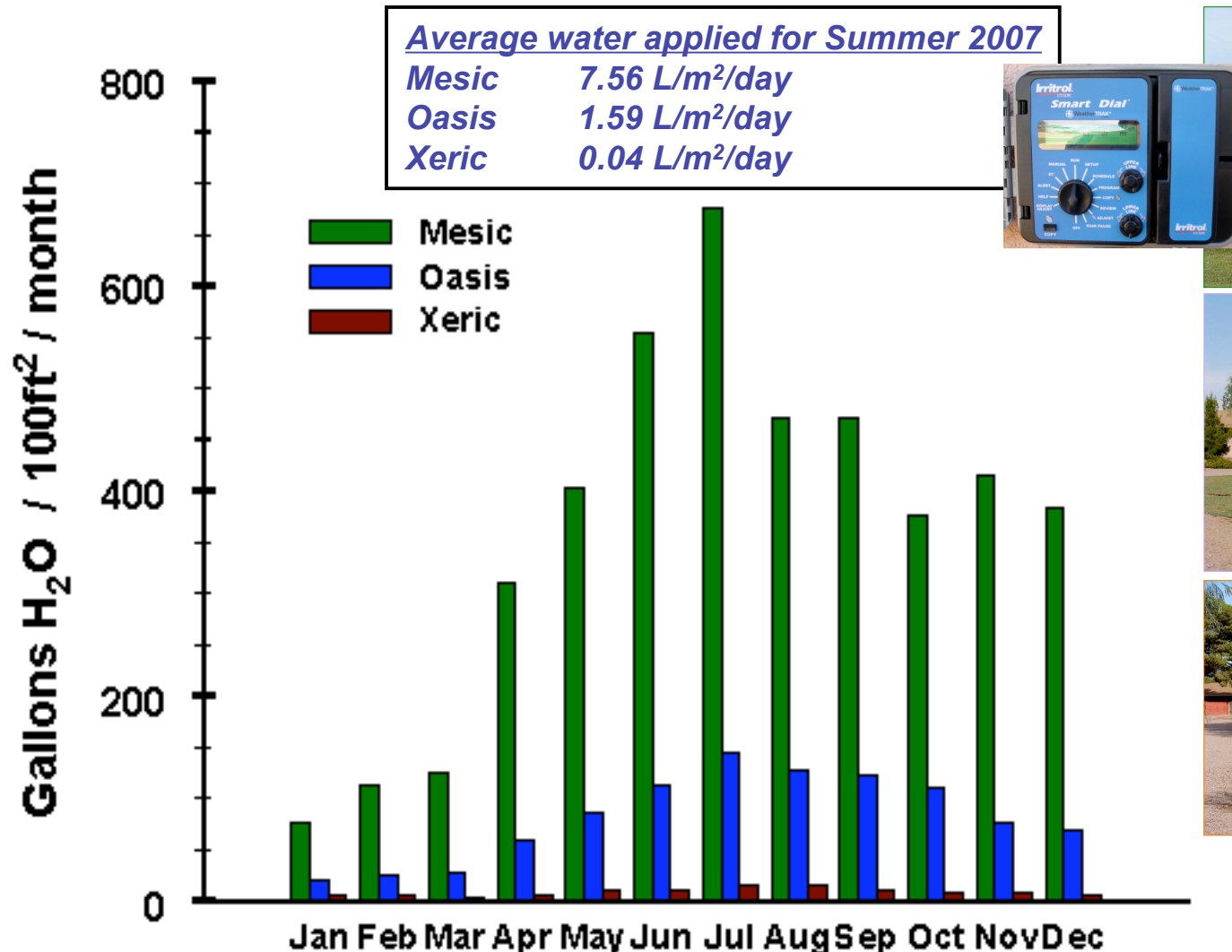


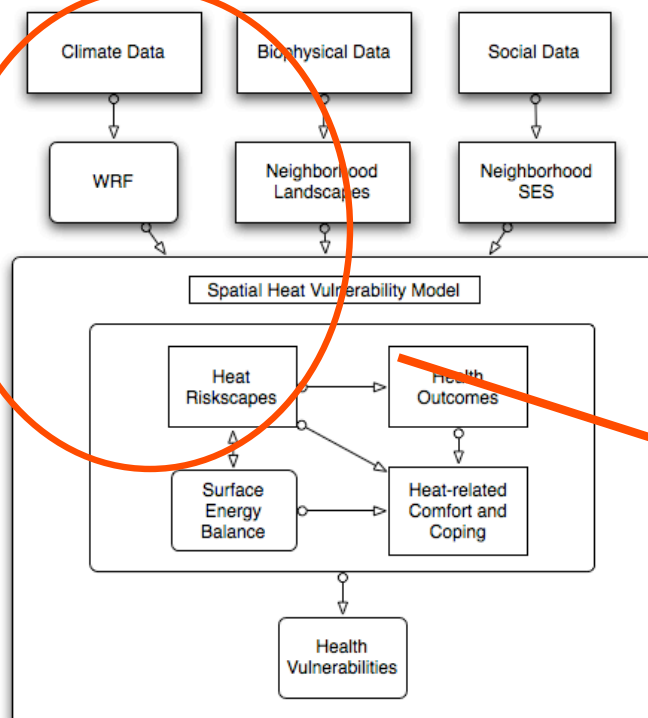
- water

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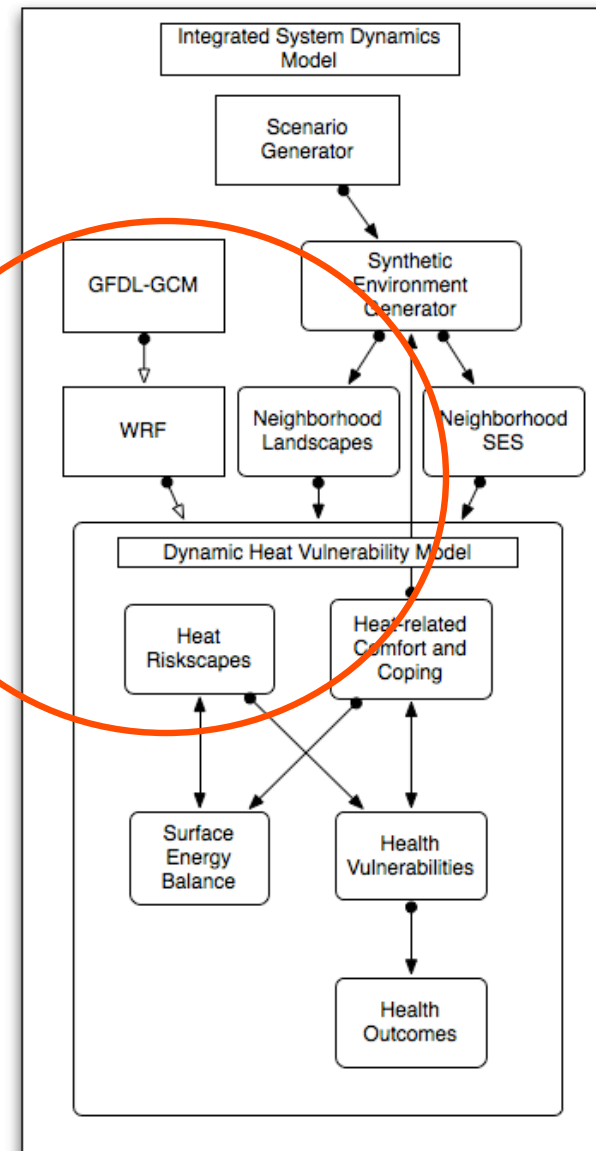
***Monthly landscape water use at ASU experimental plots, 2007.
Irrigation controlled by SMART irrigation controllers.***





Legend for Figure 1 and 2

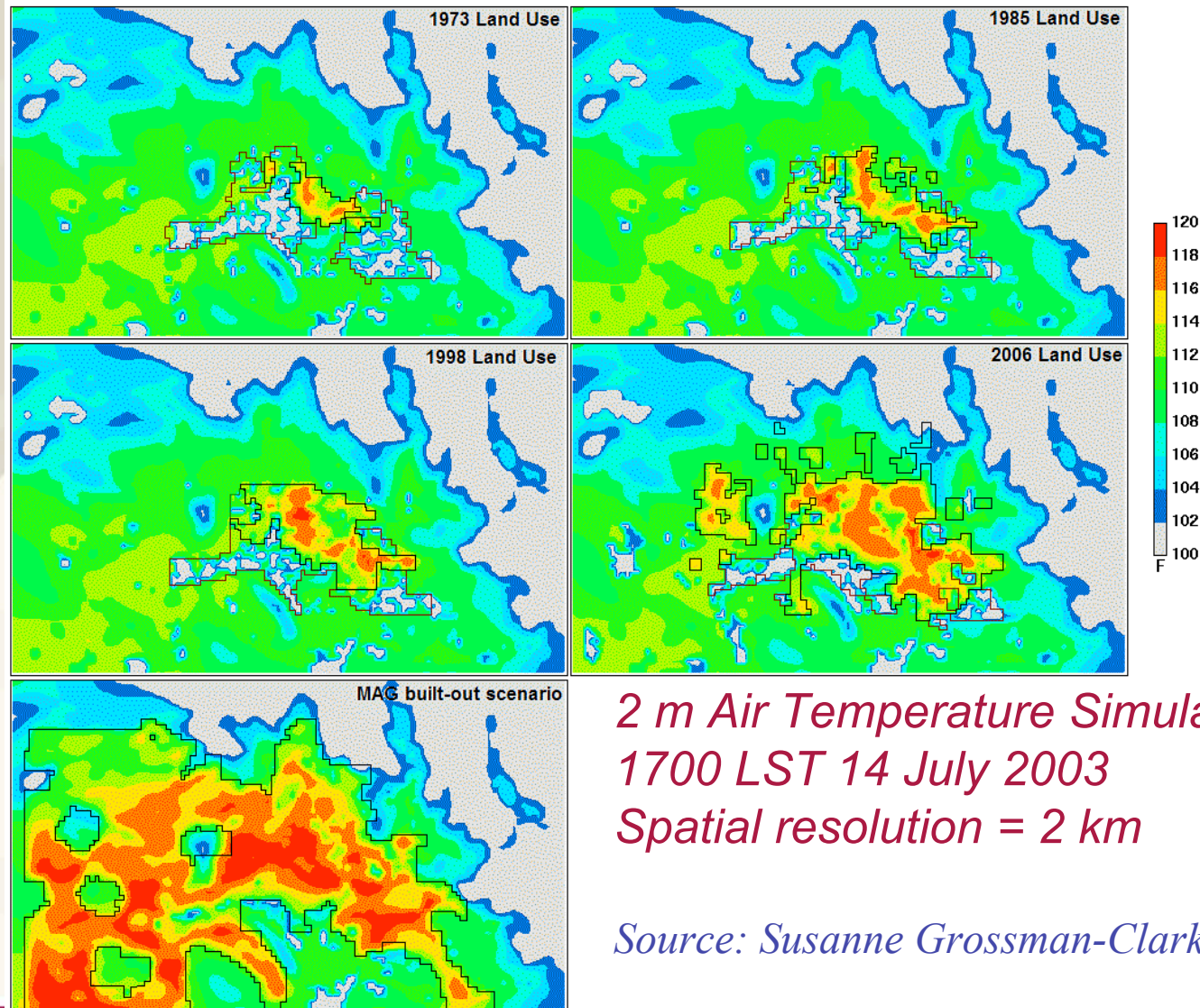
- Data output representing historical time-series data or single-run model output.
- Model input for parameter estimation or reconciliation of spatial scales
- Outputs are scenario dependent
- Dynamically linked model input
- Model calibration/validation
- Data set
- Model to develop or implement





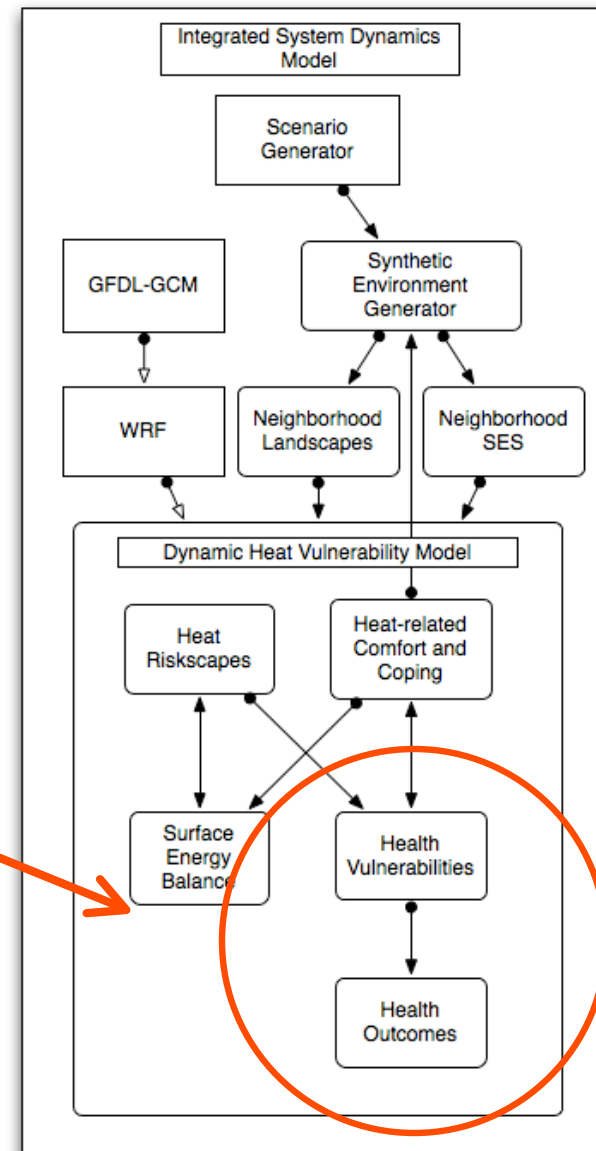
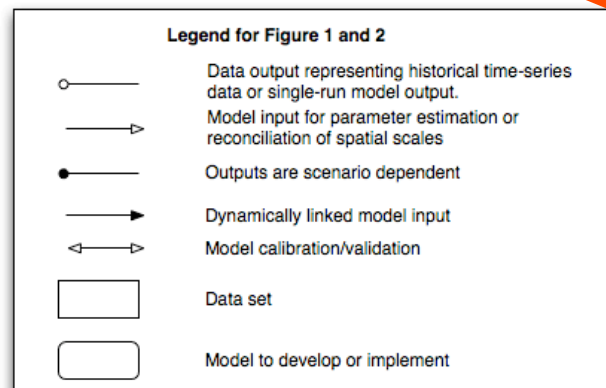
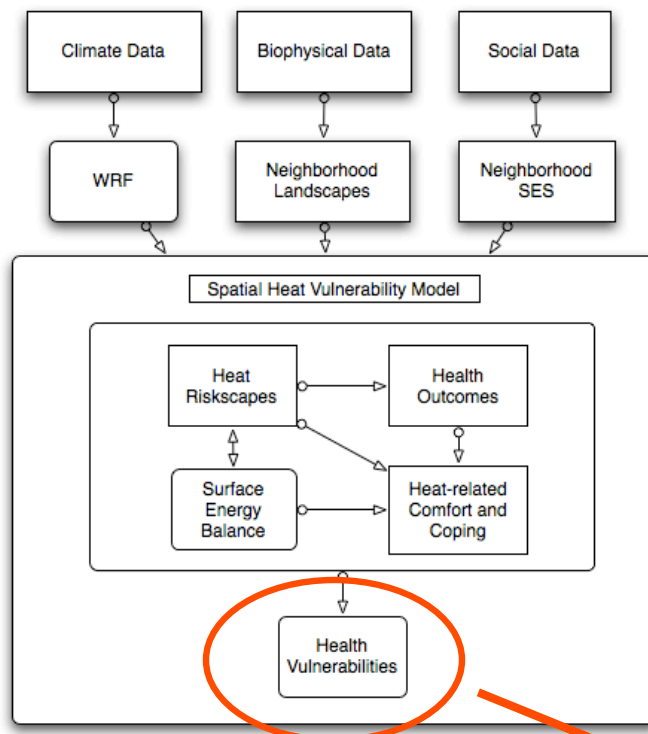
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Expanding Phoenix Heat Island



*2 m Air Temperature Simulations
1700 LST 14 July 2003
Spatial resolution = 2 km*

Source: Susanne Grossman-Clarke

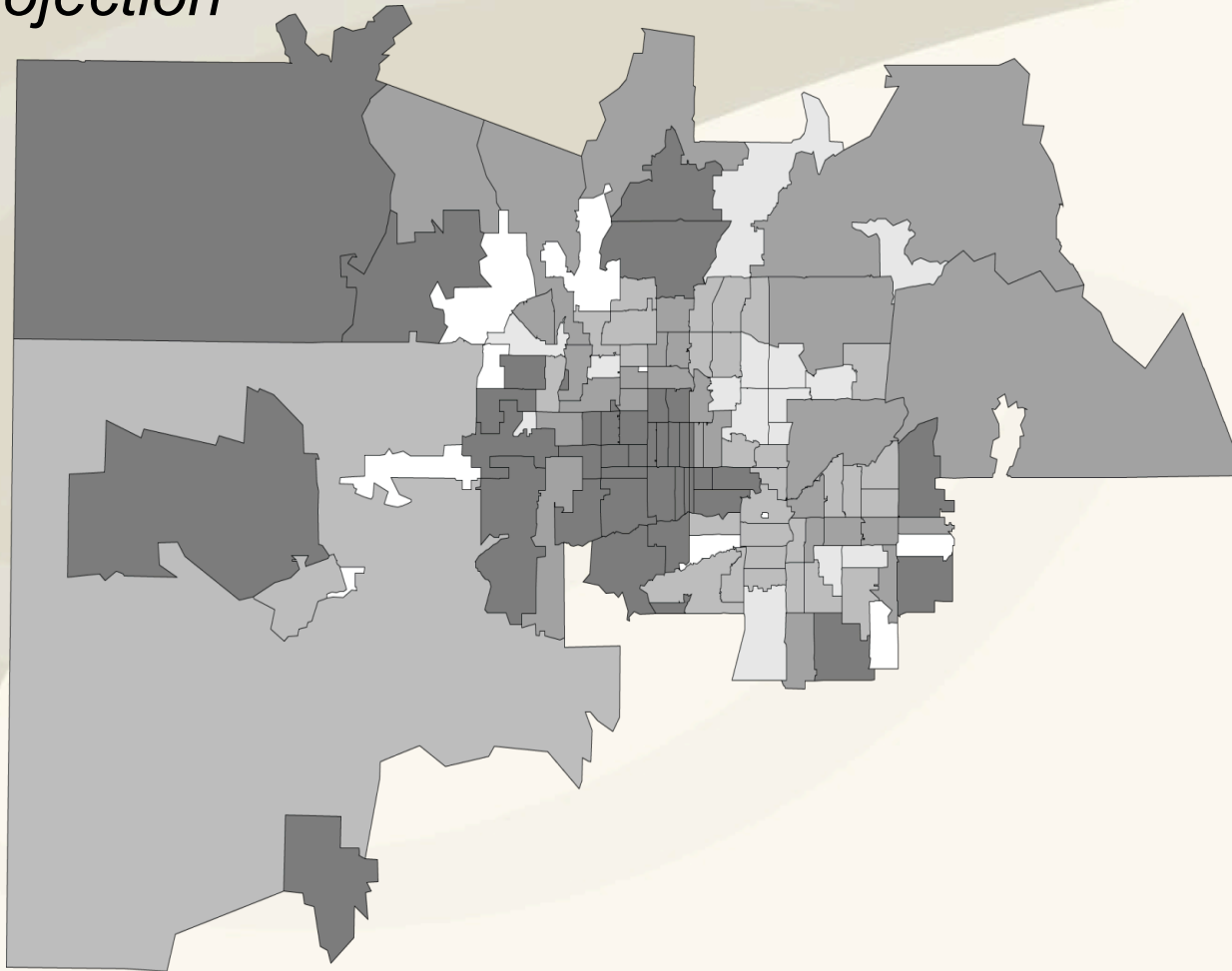




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Percent of Maricopa County in AZHQ

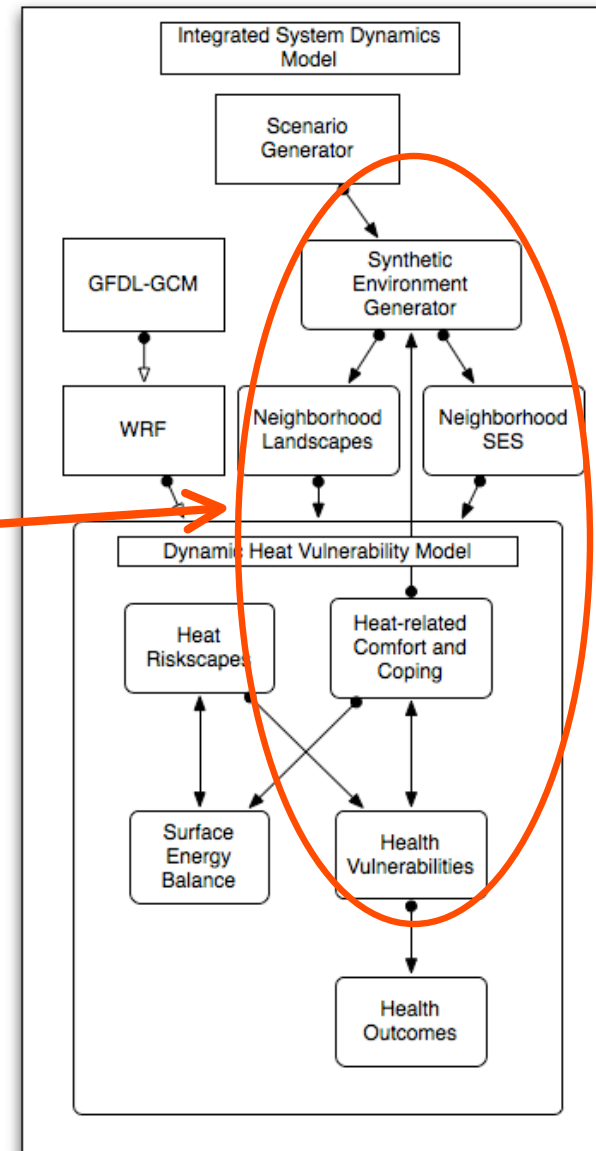
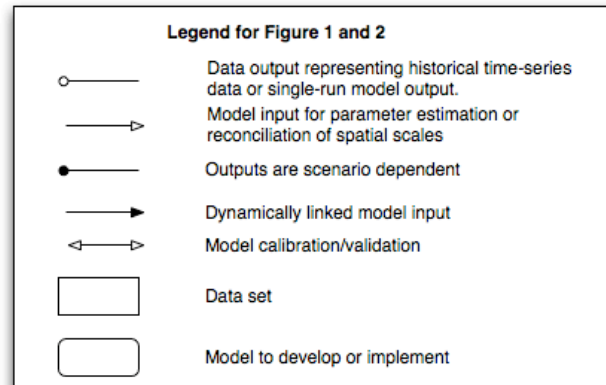
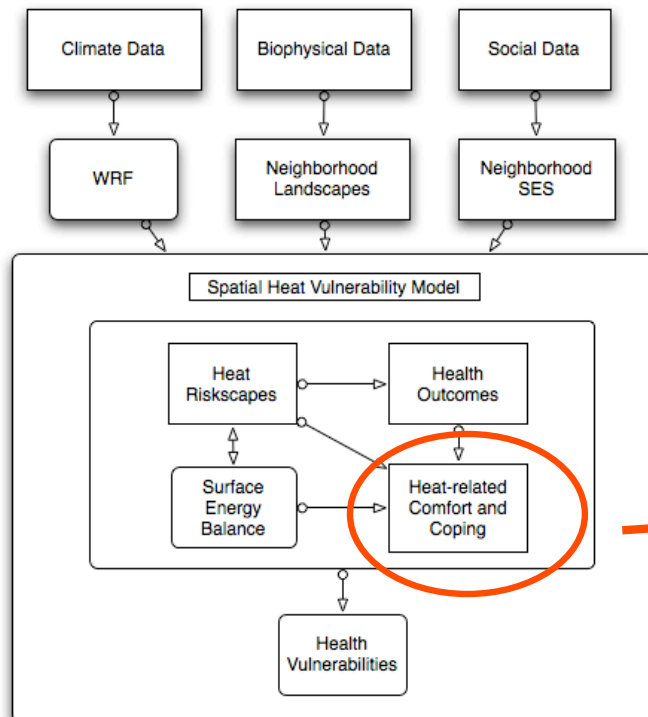
Patients receiving services 2004 – 2008 versus 2007 Census projection



90% + 75 – 89% 60 – 74% < 60%
N/A

CHiR
Center for Health
Information & Research

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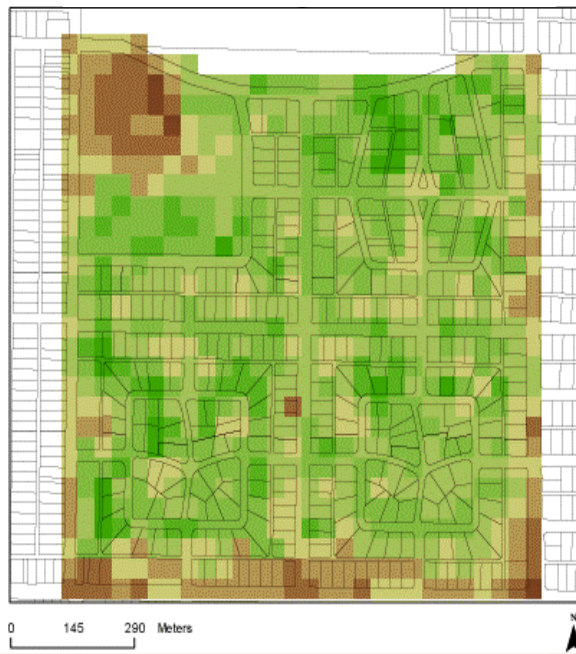




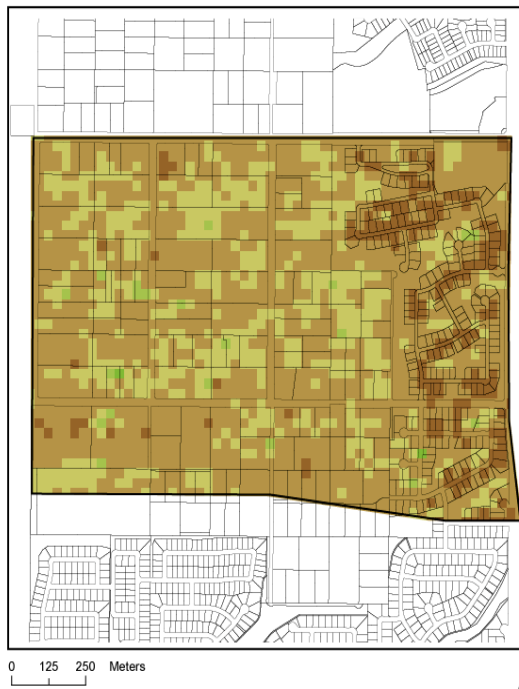
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Comparison of Vegetation Index in 3 Neighborhoods

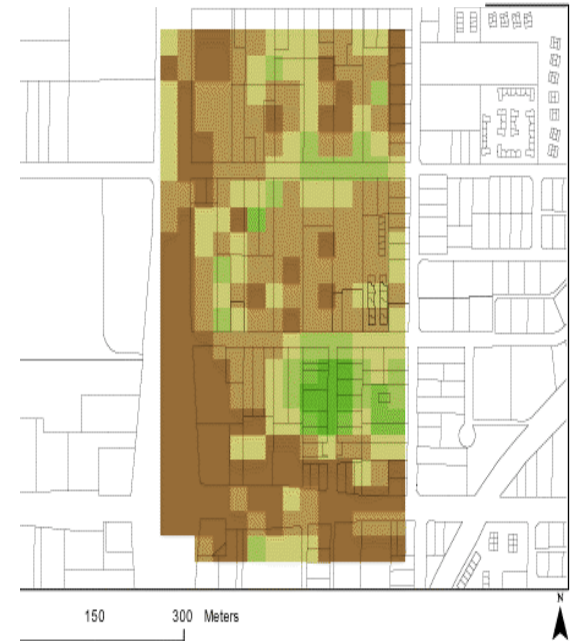
Historic Anglo Phoenix



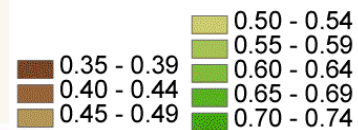
North Desert Ranch



Black Canyon Freeway



SAVI Derived from 2000 Landsat

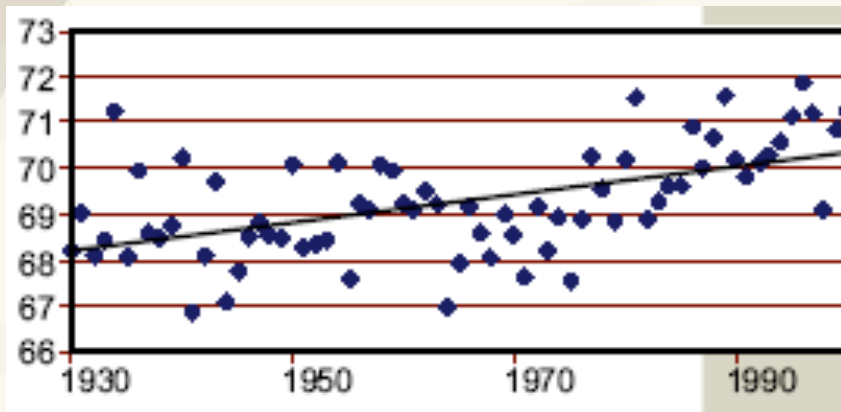




Perceptions of Climate Change (in preparation)

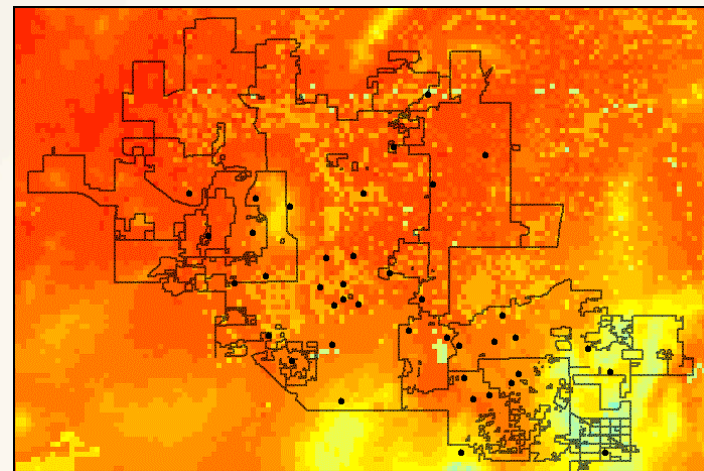
- Public opinion polls indicate Americans report a high level of awareness to global climate change*
- Examine variable temperature conditions and perceived risk to climate change at two spatial scales*

Temp in Valley Over Time



Source: Brazel et al. 2002

Temp in Neighborhood

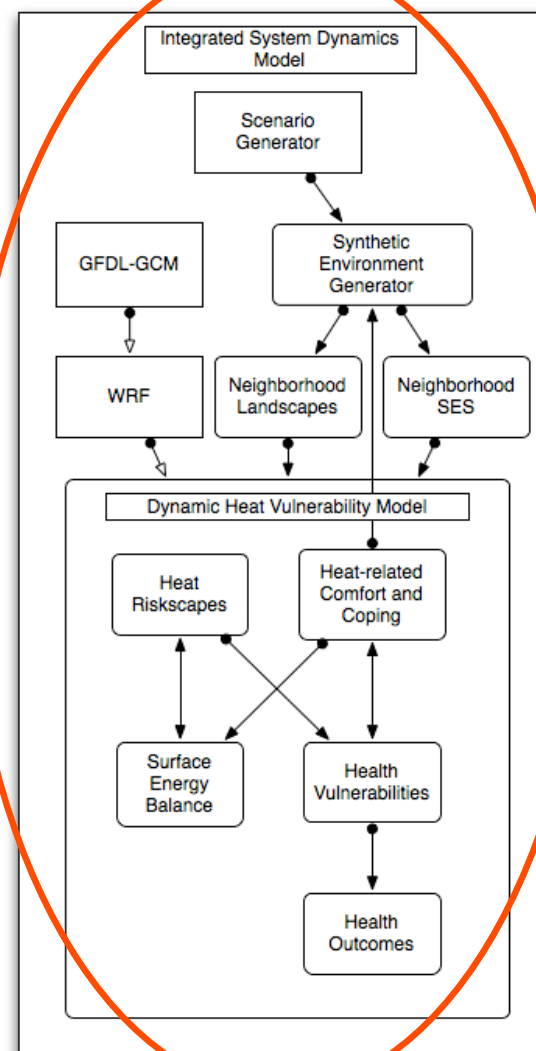
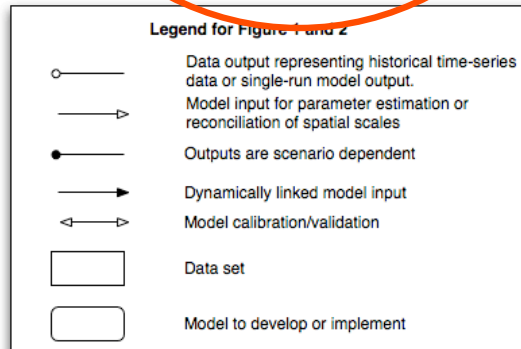
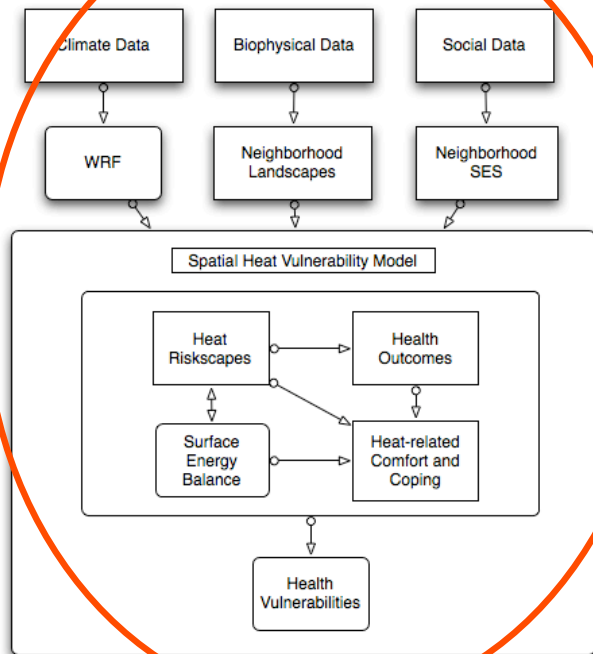


Grossman-Clarke:

WRF Simulation July 17, 2005 5pm



System Dynamics approach





The Decision Theater – Platform for visualization, modeling, and collaboration in complex, interdisciplinary domains



Decision Center for a Desert City, WaterSim.



Some of *WaterSim*'s many user-adjustable variables

W
E
T

D
R
Y

**Colorado
River Supply**

**Salt-Verde
River Supply**

**Land Use &
Population**

**Water sources
& Groundwater**

**Water Uses
& Demand**

Slider bars on graphs allow alternate futures to be assessed in real time

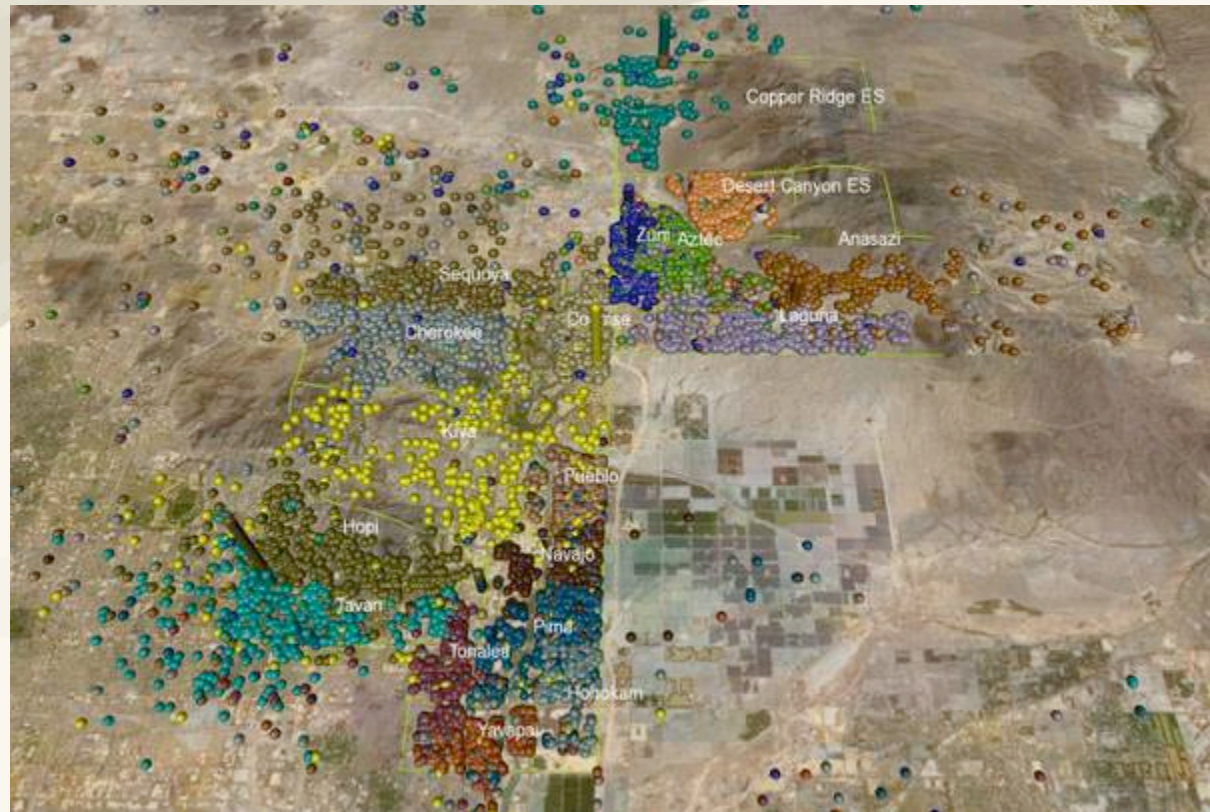


Questions?





Minerva is a GIS-based Virtual Reality application developed at ASU



Color-coding used to show students from different schools within a district can similarly depict species distributions



WaterSim, a decision-making tool for DCDC

- *WaterSim* is a graphical programming tool developed for DCDC, which lets groups of individuals (experts or lay) explore alternative future scenarios for water needs in Central Arizona using the Decision Theater
- *WaterSim* links dozens of viewer-adjustable variables including future projections of water supply, results of regionalized global climate models, water policies and prices, population projections, and land use options
- The flow chart below shows how *WaterSim* can link different models

